[CLAIMS]

What is claimed is:

1. In a method in constructing a zig-zag slab laser with an one-dimensional beam-expanding laser cavity, capable of i) realizing intense multipass pumping, ii) effectively solving thermal distortion and cooling problems, iii) providing stress-free and O-ring-free slab mounting, iv) obtaining high-power TEM_{00}-mode operation, v) achieving extra-high-power intracavity SHG, vi) operating in either CW mode or pulsed mode, and vii) minimizing spatial hole burning whereby realizing high power operation at minor laser lines, comprising the steps of

A. selecting a pump source means, from the group consisting of a diode bar means and a multiple-pump-source means having a single pump wavelength or multiple pump wavelengths, to provide a relevant pumping light for pumping;

B. making a laser slab means, wherein said laser slab means has a substantially rectangular cross section with two major surfaces, two minor surfaces, and two opposing end faces which are cut at a Brewster angle or square-cut;

C. constructing a slab laser pump head for pumping, housing and cooling said laser slab means;

D. constructing said one-dimensional, beam-expanding laser cavity by mean of an one-dimensional beam expander means, wherein

(1) said laser cavity includes at least two cavity mirrors,

(2) said pump head is placed within said laser cavity for lasing at a fundamental wavelength,

(3) said one-dimensional beam-expanding laser cavity causes laser light to resonate along a zig-zag optical path between said two major surfaces of said laser slab means via total-internal-reflection,

(4) said laser cavity has a noncircular or line-shaped spatial mode cross-section at least within part of said laser cavity which is substantially compatible with the cross-section of said laser slab means, and

(5) whereby i) obtaining mode-matched pumping, TEM_{00}-mode operation and all-out energy extraction from said laser slab means, ii) employing said laser slab means with a large aspect ratio of its height to its thickness, so as to effectively solve thermal distortion problems, and iii) achieving high-performances of intracavity harmonic generations and true CW operation over wide spectra ranges, from red, blue to ultraviolet; and

E. optionally inserting a Q-switch into the expanded mode portion of said cavity for a pulsed mode operation, wherein the cross-section of the laser beam which passes through said Q-switch is a line rather than a point, so that the power density impinged on said Q-switch is decreased significantly, whereby avoiding optical damages and acquiring extra-high energy operations.

2. In the method of claim 1, further comprising the steps of

A. by mean of an optical duct means, constructing said pump head in a manner of optical total-internal-reflection configuration at least for its major portion, leading to confining said pumping light within said pump head via total-internal-reflection considerably during the entire pumping process;

wherein said pumping light, once entering said pump head and said optical duct means, undergoes zig-zag optical paths, multiple reflections and multiple travels through or within said laser slab means until it is absorbed; whereby

(1) significantly reducing multiple reflection losses caused by the zig-zag optical paths,

(2) confining said pumping light within said pump head to achieving effective and efficient uniform pumping and minimizing thermal aberration, and

(3) with the use of said optical duct means, acquiring zig-zag pump paths and eliminating hot spot issue caused by directly diode bar pumping;

B. setting a coupling manner to couple said pumping light to a pump entrance means including at least one pump entrance for the input of said pumping light into said optical duct means, wherein said pump source means is external to said optical duct means;

C. predetermining the location and orientation for said laser medium means, said optical duct means and pump entrance means in effective operative relationship, whereby facilitating the multipass pump process, minimizing the escape loss and obtaining efficient and uniform pumping;

D. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, refractive index and dopant concentration, whereby facilitating efficient and uniform pumping, laser operation and effective cooling; and

E. in order to protect the TIR interface for said two major surfaces of said laser slab means and for said optical duct means, selecting an approach from the group including:

(1) by use of a mental foil or pressed mental layer, including aluminum, indium and silver foil,

(2) by use of a thick metal coating,

(3) by use of a metalized mirror surface,

(4) by use of a coating or film with a low refractive index, including cement J91, silicon gel, optical-grade epoxy, SiO_2 coating and Teflon AF 1600 coating, and

(5) by use of a clear optical window with a low refractive index, including MgF_2.

3. In the method of claim 2, further comprising the steps of:

A. designating pump trip direction as the average propagation direction of the zig-zag pumping light within said optical duct means; and

B. selecting a construction for said slab laser pump head from the group including:

(1) a first construction, wherein

a) said pump light enters and multiply passes through said laser slab means via at least one said major surface,

b) said laser slab means is sandwiched between two coolant passages through its two major surfaces, said coolant passage is formed between said optical duct means and said laser slab means, and

c) said pump trip direction is perpendicular to said major surfaces and parallel to said minor surfaces;

(2) a second construction, wherein

a) said pump light enters and multiply passes through said laser slab means via at least one said major surface until said pumping light is absorbed,

b) said laser slab means is sandwiched by and in contact with said optical duct means via its two major surfaces, said optical duct is of high thermal conductivity for heat transfer and effective cooling, and

c) said pump trip direction is perpendicular to said major surfaces and parallel to said minor surfaces;

(3) a third construction in which said laser slab means is conductively cooled, wherein

a) said pumping light enters said laser slab means via said major surface of said laser slab means,

b) one said major surface of said laser slab means is interfaced with said optical duct means, the other one of said major surfaces is conductively cooled,

c) in order to reflect pumping light and to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected for the cooling side of said slab means: i) it is covered by a metal foil which may have a high reflectivity, ii) it is interfaced with a metalized mirror surface of a heat sink, and iii) it is HR coated at the pump wavelength, and the SiO_2 or MgF_2 material is used as the first layer of the HR coating,

d) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected for the non-cooling side of said slab means: i) it has a protective coating or bonding material, ii) it has a MgF_2 window, and iii) it is distanced from said optical duct means with an interstitial air, and

e) said pump trip direction is perpendicular to said major surfaces and parallel to said minor surfaces;

(4) a fourth construction in which said laser slab is conductively cooled, wherein

a) said optical duct means consists of one or two members of thin slab-shaped optical duct which has a substantially rectangular cross section and two broad surfaces,

b) said optical duct means is interfaced with at least one major surface of said laser slab means via its said broad surface where said pumping light enters into said laser slab means along zig-zag optical paths,

c) said optical duct means is of high thermal conductivity,

d) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected: i) said laser slab means has a protective coating, and ii) said optical duct means has a lower refractive index than that of said laser slab means,

e) at least one said major surface of said laser slab means is conductively cooled via said optical duct means, and

f) said pump trip direction is parallel to said major surfaces;

(5) a fifth construction in which said laser slab is conductively cooled, wherein

a) said optical duct means consists of at least two members of thin planar optical duct, each one has two broad surfaces,

b) said laser slab means is sandwiched between said two members of thin planar optical duct via said major surfaces firstly, and then sandwiched between two heat sinks via said two members of thin planar optical duct symmetrically,

c) said optical duct means is interfaced with two said major surfaces of said laser slab means via its said broad surfaces where said pumping light enters into said laser slab means along zig-zag optical paths,

d) said optical duct means is of high thermal conductivity and thermally in contact with said two heat sink via its said broad surfaces, said laser slab means is conductively cooled via said optical duct means,

e) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected: i) said laser slab means has a protective coating, and ii) said optical duct means has a lower refractive index than that of said laser slab means,

f) optionally said heat sink has a mirrored surface which is interfaced with said broad surfaces of said optical duct means whereby to reflect pumping light and realize multipass pumping, and

g) said pump trip direction is parallel to said major surfaces; and

(6) a sixth construction with the so-called edge pumping in which said laser slab is conductively cooled, wherein

a) said pumping light enters said laser slab means via at least one said minor surface,

b) said laser slab means is conductively cooled via a metal foil and heat spreader and via its two major surfaces, said metal foil is used for preserving total-internal-reflection for zig-zag laser paths and zig-zag pump paths, and

c) said pump trip direction is perpendicular to said minor surfaces and parallel to said major surfaces.

4. In constructing said first construction as recited in claim 3, further comprising the steps of

A. building a laser slab assembly which is selected from the group comprising

(1) first laser slab assembly, which additionally comprises the steps of

a) selecting two members of planar optical duct serving as said optical duct means,

b) selecting two slab holders and setting them parallel to each other,

c) making two slots at both of said either slab holder,

d) setting the two ends of said laser slab into said either slot with a bonding material whereby elastically supporting said laser slab and providing stress-free and O-ring-free slab mounting and sealing,

e) coating at the end part of said laser slab to save the TIR interface in case,

f) symmetrically bounding said optical duct means to two said slab holders with a sealant, whereby forming said two coolant passages between said major surfaces of said laser slab and said two planar

optical ducts, and forming two windows for said pumping light entering and pumping said major surfaces of said laser slab means, and

g) building said first laser slab assembly with the use of said laser slab means, said optical duct means and said two slab holders; and

(2) second laser slab assembly, which additionally comprises the steps of

a) selecting two members of planar optical duct serving as said optical duct means,

b) selecting a slab fixer means optical clear to said pumping light,

c) setting the two ends of said laser slab into said slab fixer means with a bonding material whereby elastically supporting said laser slab and providing stress-free and O-ring-free slab mounting and sealing,

d) coating at the end part of said laser slab to save the TIR interface in case,

e) symmetrically bounding said optical ducts means to said slab fixer means with a sealant, whereby forming said two coolant passages between said major surfaces of said laser slab means and said two planar optical ducts, and forming two windows for said pumping light entering and pumping said major surfaces of said laser slab means, and

f) building said second laser slab assembly with the use of said laser slab means, said optical duct means and said slab fixer means;

B. selecting engineering parts, including a lower cover plate with two coolant passages, a upper cover plate with two coolant passages, a pair of plenum, a inlet, an outlet, two insulators for said laser slab means, and four transparent silicon rubber O-rings; and

C. assembling said engineering parts together with said laser slab assembly in effective operative way, wherein i) said laser slab assembly is sandwiched between said lower cover plate and said upper cover plate via said O-rings, and ii) O-ring's plane is perpendicular to said major surface of said laser slab.

5. In the method of claim 1, in order to realize high power operation at a minor laser line desired, particularly for the generation of high-power red and blue coherent light for laser projection display, further comprising the steps of

A. selecting a desired output wavelength for said minor laser line;

B. producing a gain region with intense pumping within said laser slab means;

C. maximizing the cavity Q factor of said laser cavity for said desired output wavelength;

D. minimizing the cavity Q factor of said laser cavity for undesired laser lines;

E. locating said gain region at an optimum position, preferably at ½ L, ¼ L, ¾ L, 1/6 L and 5/6 L, wherein i) L is designated as the optical length of said laser cavity, ii) within said optimum position there would be the highest possibility for a pair of longitudinal modes with a spatially anti-correlated relationship to take place and to occupy most of said gain region spatially, whereby minimizing spatial hole burning and restraining said gain region available to undesired major laser lines;

F. making said laser cavity have a large enough optical length L to prolong an out of phase region to best match said gain region, wherein within the out of phase region two peaks in the standing wave patterns corresponding to the pair of anti-correlated longitudinal modes are out of phase;

G. setting said gain region or said laser slab means have a limited length less than 3-cm to best match the out of phase region, whereby restraining said gain region available to undesired major laser lines; and

H. keeping the dopant concentration of said laser slab as low as possible while keeping the absorption efficiency high for said pumping light.

6. In the method of claim 5, in order to generate high-power red and blue coherent light via intracavity SHG, further comprising the steps of

A. inserting a SHG crystal means into said laser cavity;

B. selecting said SHG crystal means from the group including

(1) a regular SHG crystal means,

(2) a periodically poled crystal means with quasi-phase-matching,

(3) a slab-shaped SHG crystal means, made from a single piece of SHG crystal, in cooperation with said noncircular or line-shaped spatial mode cross-section of said laser cavity, and

(4) a slab-shaped SHG crystal means consisting of several individual SHG crystals parallel positioned, in cooperation with said noncircular or line-shaped spatial mode cross-section of said laser cavity;

C. selecting a beam profile for laser output from the group including

(1) a regular beam profile, and

(2) a line-shaped beam profile, whereby directly applying to the Grating Light Valve technology; and

D. optionally inserting a waveplate into the expanded mode portion of said cavity to adjust the polarization situation for the laser operation and SHG process.

7. In the method of claim 1, in order to realize extra-high power or energy operation with intracavity frequency conversions, further comprising the steps of

A. inserting a slab-shaped nonlinear crystal means into the expanded mode portion of said cavity to realize intracavity SHG, wherein the cross-section of the laser beam which passes through said nonlinear crystal means is a line rather than a point, so that the power density impinged on said nonlinear crystal means is decreased significantly, whereby avoiding optical damages and obtaining extra-high power or energy intracavity frequency conversions;

B. selecting said nonlinear crystal means from the group including

(1) a slab-shaped SHG crystal means made from a single piece of SHG crystal,

(2) a slab-shaped SHG crystal means consisting of several individual SHG crystals parallel positioned,

(3) a slab-shaped SHG crystal means and a slab-shaped THG crystal means positioned serially, and

(4) a slab-shaped SHG crystal means, a slab-shaped THG crystal means and a slab-shaped FHG crystal means positioned serially;

C. selecting a beam profile for laser output from the group including

(1) a regular beam profile, and

(2) a line-shaped beam profile, whereby directly applying to the Grating Light Valve technology; and

D. optionally inserting a waveplate into the expanded mode portion of said cavity to adjust the polarization situation for the laser operation and SHG process.

8. In the method of claim 1, in order to realize multiple wavelengths operation concurrently, including white light output, further comprising the steps of

A. selecting two or more certain output wavelengths for laser operation;

B. selecting said laser slab means from the group including

(1) several individual laser slabs parallel positioned, wherein each said laser slab is made from a different laser material with a different doping level and corresponding to said one certain output wavelength, and

(2) single laser slab with a broad spectral band;

C. producing a gain regions for each said individual laser slab or for said single laser slab;

D. maximizing the cavity Q factor of said laser cavity for said output wavelengths;

E. minimizing the cavity Q factor of said laser cavity for other potential laser wavelengths;

F. locating said laser slab means at an optimum position, preferably at ½ L, ¼ L, ¾ L, 1/6 L and 5/6 L, wherein i) L is designated as the optical length of said laser cavity, ii) within said optimum position there would be the highest possibility for a pair of longitudinal modes with a spatially anti-correlated relationship to take place and to occupy most of said gain region spatially, whereby minimizing spatial hole burning and restraining said gain region available to other potential laser wavelengths;

G. selecting said laser cavity have a large enough optical length L to prolong an out of phase region to best match said laser slab means, wherein within the out of phase region two peaks in the standing wave patterns corresponding to the pair of anti-correlated longitudinal modes are out of phase;

H. setting said laser slab means have a limited length to best match the out of phase region, whereby restraining said gain region available to other potential laser wavelengths;

I. inserting a slab-shaped SHG crystal means into the expanded mode portion of said cavity to realize intracavity SHG, wherein said slab-shaped SHG crystal means consists of several individual SHG crystals parallel positioned, each said SHG crystal is collaborated with said individual laser slab or the different portion of said single laser slab and corresponding to producing said one certain output wavelength;

J. selecting said individual SHG crystal from the group including

(1) a regular SHG crystal, and

(2) a periodically poled crystal means with quasi-phase-matching;

K. selecting a discrete-wavelength zero-dispersion prism beam expander to be served as said one-dimensional beam expander means; and

L. optionally inserting a waveplate means into the expanded mode portion of said cavity to adjust the polarization situation for the laser operation and SHG process; wherein said waveplate means consists of several individual waveplate parallel positioned, each said waveplate is collaborated with said individual SHG crystal and corresponding to said one certain output wavelength.

9. In a method in constructing a multipass pump head for DPSS lasers, fiber lasers and fiber amplifiers, capable of realizing intense uniform pumping and producing and amplifying coherent light, comprising the steps of

A. selecting a pump source means, from the group consisting of a diode bar means and a multiple-pump-source means having a single pump wavelength or multiple pump wavelengths, to provide a relevant pumping light for pumping;

B. selecting a laser medium means from the group including

(1) laser chips, laser rods and laser slabs, made from regular laser materials or tunable laser materials, and

(2) optical fibers with a rare-earth-doped core;

C. setting a coupling manner to couple said pumping light to a pump entrance means including at least one pump entrance for the input of said pumping light into said multipass pump head; and

D. constructing said multipass pump head by use of a multipass formation to confine said pumping light, wherein said pumping light, once entering, undergoes multiple reflections and multiple travels through or within said laser medium means, said multipass formation is selected from the group consisting of

(1) a first multipass formation with the use of optical total-internal-reflection configuration, which additionally comprises the steps of making said multipass pump head as a TIR-guide pump head by mean of an optical duct means, leading to confining said pumping light within said TIR-guide pump head mainly via total-internal-reflection during the entire pumping process; wherein said pumping light, once entering said pump head and said optical duct means, will undergo zig-zag optical paths, multiple reflections and multiple travels through or within said laser medium means until it is absorbed, and ii) the escape loss possibility of unabsorbed said pumping light is at least less than 40% within one round trip pumping path, or at least less than 40% during the entire pumping process; whereby i) significantly reducing multiple reflection losses caused by the zig-zag optical paths, ii) confining said pumping light within said pump head to achieve effective and efficient uniform pumping; and iii) with the use of said optical duct means, eliminating hot spot issue caused by directly diode bar pumping for DPSS lasers;

(2) a second multipass formation with the use of optical graded-index or step-index configuration,

(3) a third multipass formation with the use of a noncircular-profile reflector means which has a noncircular cross-section with a convex and closed boundary, wherein i) said laser medium means is a laser rod

means which has a lasing axis and a transverse plane perpendicular to said lasing axis, said noncircular cross-section is in said transverse plane, and ii) said laser rod is surrounded by a cooling channel,

(4) a fourth multipass formation with the use of a double-layer reflector means, and

(5) a fifth multipass formation with the use of optical spatial filter or the like configuration; and

E. housing and cooling said laser medium means.

10. In constructing said TIR-guide pump head by use of said first multipass formation as recited in claim 9, in order to make a slab laser pump head of said TIR-guide pump head for zig-zag slab lasers, further comprising the steps of

A. making a laser slab means of said laser medium means, wherein said laser slab means has a substantially rectangular cross section with two major surfaces, two minor surfaces, and two opposing end faces which are cut at a Brewster angle or square-cut;

B. predetermining the location and orientation for said laser medium means, said optical duct means and pump entrance means in effective operative relationship, whereby facilitating the multipass pump process, minimizing the escape loss and obtaining efficient and uniform pumping;

C. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, refractive index and dopant concentration, whereby facilitating efficient and uniform pumping, laser operation and effective cooling;

D. in order to protect the TIR interfaces for said TIR-guide pump head, selecting an approach from the group including:

(1) by use of a mental foil or pressed mental layer, including aluminum, indium and silver foil,

(2) by use of a thick metal coating,

(3) by use of a metalized mirror surface,

(4) by use of a coating or film with a low refractive index, including cement J91, silicon gel, optical-grade epoxy, SiO_2 coating and Teflon AF 1600 coating, and

(5) by use of a clear optical window with a low refractive index, including MgF_2; and

E. selecting said slab laser pump head from the group including:

(1) a first slab laser pump head, wherein

a) said pump light enters and multiply passes through said laser slab means via said two major surfaces, and

b) said laser slab means is sandwiched between two coolant passages via said two major surfaces, said coolant passage is formed between said optical duct means and said laser slab means;

(2) a second slab laser pump head, wherein

a) said pump light enters and multiply passes through said laser slab means via at least one said major surface until said pumping light is absorbed, and

b) said laser slab means is sandwiched by and in contact with said optical duct means via its two major surfaces, said optical duct is of high thermal conductivity for heat transfer and effective cooling;

(3) a third slab laser pump head in which said laser slab means is conductively cooled, wherein

a) said pumping light enters said laser slab means via said major surface of said laser slab means,

b) one said major surface of said laser slab means is interfaced with said optical duct means, the other one of said major surfaces is conductively cooled,

c) in order to reflect pumping light and to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected for the cooling side of said slab means: i) it is covered by a metal foil which may have a high reflectivity, ii) it is interfaced with a metalized mirror surface of a heat sink, and iii) it is HR coated at the pump wavelength, and the SiO_2 or MgF_2 material is used as the first layer of the HR coating, and

d) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected for the non-cooling side of said slab means: i) it has a protective coating or bonding material, ii) it has a MgF_2 window, and iii) it is distanced from said optical duct means with an interstitial air;

(4) a fourth slab laser pump head in which said laser slab means is conductively cooled, wherein

a) said optical duct means consists of one or two members of thin slab-shaped optical duct which has a substantially rectangular cross section and two broad surfaces,

b) said optical duct means is interfaced with at least one major surface of said laser slab means via its said broad surface where said pumping light enters into said laser slab means along zig-zag optical paths,

c) said optical duct means is of high thermal conductivity,

d) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected: i) said laser slab means has a protective coating, and ii) said optical duct means has a lower refractive index than that of said laser slab means, and

e) at least one said major surface of said laser slab means is conductively cooled via said optical duct means;

(5) a fifth slab laser pump head in which said laser slab means is conductively cooled, wherein

a) said optical duct means consists of at least two members of thin planar optical duct, each one has two broad surfaces,

b) said laser slab means is sandwiched between said two members of thin planar optical duct via said major surfaces firstly, and then sandwiched between two heat sinks via said two members of thin planar optical duct symmetrically,

c) said optical duct means is interfaced with two said major surfaces of said laser slab means via its said broad surfaces where said pumping light enters into said laser slab means along zig-zag optical paths,

d) said optical duct means is of high thermal conductivity and thermally in contact with said two heat sink via its said broad surfaces, said laser slab means is conductively cooled via said optical duct means,

e) in order to preserve the TIR interface for the laser zig-zag path within said laser slab means, one of the following procedures is selected: i) said laser slab means has a protective coating, and ii) said optical duct means has a lower refractive index than that of said laser slab means, and

f) optionally said heat sink has a mirrored surface which is interfaced with said broad surfaces of said optical duct means whereby to reflect pumping light and realize multipass pumping;

(6) a sixth slab laser pump head with the so-called edge pumping in which said laser slab means is conductively cooled, wherein

a) said pumping light enters said laser slab means via at least one said minor surface along zig-zag optical paths,

b) said optical duct means is interfaced with at least one said minor surface of said laser slab means via a transparent bonding material or interstitial air, and

c) said laser slab means is conductively cooled via its two major surfaces;

(7) a seventh slab laser pump head in which said laser slab means is conductively cooled, wherein

a) said laser slab means is extra-thin with a thickness of less than 1 mm, more particularly less than 0.5 mm,

b) said laser slab means is integrated with or embedded into said optical duct means,

c) said laser slab means has a line-shaped gain region,

d) said optical duct means is transparent at both the pump and laser wavelengths and its refractive index is the same as or close to that of said laser slab means,

e) a joint approach is used, including, i) a high temperature, optical-grade epoxy or glue interposed between said laser slab means and said optical duct means, ii) diffusion-bonding, and iii) frit,

f) the lasing direction is perpendicular to said line-shaped gain region, and

g) said slab laser means together with said optical duct means is conductively cooled via an HR mirror or mirrored surface, said mirror has thin substrate with high thermal conductivity, made from the group including copper, sapphire, undoped YAG and MgF_2, said HR mirror serves as a rear or fold mirror for laser operations, its other side is going to contact a heat sink via a metal foil and heat spreader sometimes optionally; and

(8) a eighth slab laser pump head in which said laser slab means is conductively cooled, wherein

a) said laser slab means has a line-shaped gain region,

b) said optical duct means is transparent at pump wavelengths,

c) the lasing direction is along said line-shaped gain region,

d) said optical duct means is interfaced with said laser slab means via a transparent bonding material or interstitial air, and

e) said slab laser means is conductively cooled via its two major surfaces covered by a metal foil and heat spreader which is preserved for total-internal-reflection.

11. In constructing a high-power laser operated at a desired minor laser line by use of said seventh slab laser pump head as recited in claim 10, further comprising the steps of

A. setting a desired output wavelength for said minor laser line;

B. constructing a one-dimensional beam-expanding laser cavity having a line-shaped spatial mode cross-section within part of said laser cavity which is substantially compatible with said line-shaped gain region, wherein

(1) said laser cavity includes at least two cavity mirrors,

(2) said seventh slab laser pump head is placed within said laser cavity for lasing at said desired output wavelength; and

(3) said line-shaped gain region is perpendicular to the lasing direction;

C. producing intense pumping for said line-shaped gain region;

D. maximizing the cavity Q factor of said laser cavity for said desired output wavelength;

E. minimizing the cavity Q factor of said laser cavity for undesired laser lines;

F. locating said line-shaped gain region together with said HR mirror at an optimum position, preferably at ½ L, ¼ L, ¾ L, 1/6 L and 5/6 L, or the end of said laser cavity, wherein i) L is designated as the optical length of said laser cavity, ii) said HR mirror is served as fold cavity mirror or rear cavity mirror, iii) within said optimum position there would be the highest possibility for a pair of longitudinal modes with a spatially anti-correlated relationship to take place and to occupy most of said gain region spatially, whereby minimizing spatial hole burning and restraining said gain region available to undesired major laser lines;

G. keeping the dopant concentration of said laser slab as low as possible while keeping the absorption efficiency high for said pumping light; and

H. Optionally inserting a nonlinear crystal means into said laser cavity for intracavity frequency conversion.

12. In constructing said TIR- guide pump head by use of said first multipass formation as recited in claim 9, in order to make a thin-disk laser pump head of said TIR-guide pump head for thin-disk lasers, further comprising the steps of

A. making a laser chip means of said laser medium means;

B. constructing said optical duct means made from an optical disk, wherein

(1) said optical disk consists of substantially parallel two main surfaces perpendicular to an axis and an outer surface parallel to said axis,

(2) said two main surfaces have a same shape, and

(3) the size of said two main surfaces is significantly larger than the distance between them, i.e., the thickness of said optical disk;

C. constructing said laser chip means to be integrated with or embedded into said optical duct means, wherein

(1) said optical disk is transparent at both the pump and laser wavelengths and its refractive index is the same as or close to that of said laser chip means, and

(2) a joint approach is used for the joint of said laser chip means and said optical disk, which is selected from the group including, i) interposing a high temperature optical-grade epoxy or cement, ii) diffusion-bonding, and iii) frit;

D. in order to reflect pumping light from said outer surface while said pumping light is not reflected by said outer surface via total-internal-reflection, selecting an approach from the group including:

(1) first approach, which additionally comprises the steps of making an HR coating selectively covering predetermined portions of said outer surface, wherein there is at least one AR coated narrow spectral opening or uncoated narrow opening on said outer surface for inputting said pumping light, and

(2) second approach, which additionally comprises the steps of fitting said optical disk into a heat sink chamber means, whose inwardly facing wall matches to said outer surface geometrically and has a gold coating; wherein there is at least one opening on said chamber means for inputting said pumping light;

E. entering said pumping light toward the center area of said optical disk, wherein i) said pumping light is directed parallel to and confined between said two main surfaces via total-internal-reflection and undergoes multiple reflections via said outer surface so as to multiply and repeatedly passes through said laser chip, and ii) said coupling manner includes optical fiber coupling;

F. selecting the shape of said optical disk and said two main surfaces from the group including

(1) a circular shape, wherein said optical disk is made from the group including

a) regular optical duct, said pump head is named the **TIR-Guide Disk Pump Head**, wherein said laser chip is preferably eccentrically located within said optical disk,

b) graded-index optical duct, wherein said optical duct means has a variable refractive index in the radial direction whereby said pumping light, once entering, to be refocussed by refraction into the center area of said pump head periodically and leading to a large acceptance cone, said pump head is named the **Graded-Index TIR-Guide Disk Pump Head**, and

c) step-index optical duct, wherein said optical duct means has two sleeves with a predetermined radial extent in which the inner sleeve has a lower refractive index than that of the outer sleeve appropriately, whereby said pumping light, once entering, to be continually converged to the center area of said pump head and leading to a large acceptance cone, said pump head is named the **Step-Index TIR-Guide Disk Pump Head**,

(2) a non-circular shape, said pump head is named the **Noncircular-Profile TIR-Guide Disk Pump Head**, and

(3) a non-circular shape, said pump head is named the **Dube TIR-Guide Disk Pump Head**, wherein said optical disk consists of a pair of corner reflectors with a little difference in the size and being arranged colinearly but not coaxially with each other, ii) said pumping light is collimated before entering said

optical duct means, and iii) said pumping light is reflected by said outer surface via total-internal-reflection; and

G. conductively cooling said laser chip means surrounded by said optical disk; wherein i)said optical duct means is thermally connected with its back face to an HR mirror or mirrored surface, ii) said mirror has thin substrate with high thermal conductivity, made from the group including copper, sapphire, undoped YAG and MgF_2, and iii) said HR mirror or said mirrored surface serves as an end or fold mirror for laser operations.

13. In constructing said TIR-guide pump head by use of said first multipass formation as recited in claim 9, in order to make a laser rod pump head of said TIR-guide pump head, further comprising the steps of

A. making a laser rod means of said laser medium means;

B. constructing said laser rod means to be received in by said optical duct means and surrounded by a cooling channel means;

C. constructing two end cap assemblies for housing and cooling said laser rod;

D. selecting said optical duct means from the group including

(1) regular optical duct; wherein said laser rod is preferably eccentrically located about said optical duct means;

(2) graded-index optical duct, wherein said optical duct means has a variable refractive index in the radial direction, whereby said pumping light, once entering, to be refocussed by refraction into the center area of said pump head periodically and leading to a large acceptance cone, said pump head is named the **Graded-Index TIR-Guide Pump Head**; and

(3) step-index optical duct, wherein said optical duct means has two sleeves with a predetermined radial extent in which the inner sleeve has a lower refractive index than that of the outer sleeve appropriately, whereby said pumping light, once entering, to be continually converged to the center area of said pump head and leading to a large acceptance cone, said pump head is named the **Step-Index TIR-Guide Pump Head**; and

E. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

14. In the method of claim 13, wherein said optical duct means is made from said regular optical duct means and includes at least a first section having a longitudinal axis and a second section having a longitudinal axis, said first section longitudinal axis is parallel to and off-set from said second section longitudinal axis, said pump head is named the **Dube TIR-Guide Pump Head**.

15. In constructing said TIR-guide pump head by use of said first multipass formation as recited in claim 9, in order to make a fiber laser pump head of said TIR-guide pump head for fiber lasers and fiber amplifiers, further comprising the steps of

A. making an optical fiber means of said laser medium means, which is made up of an optical fiber with a rare-earth-doped core;

B. constructing said optical fiber means which is selected from the group consisting of

(1) a first optical fiber means, wherein

a) said optical fiber is being winded wrap by wrap, and then preferably layer by layer, to form said first optical fiber means,

b) said first optical fiber means is filled with an optical clear filler which has a refractive index same as or close to the outside cladding of said optical fiber to protect pump optical paths from distortion,

c) said first optical fiber means is in the shape of a thin plate, or thin disk plate, or thin ring plate and has two major surfaces and at least one minor surface,

d) said first optical fiber means is interfaced to said optical duct means via one or two said major surfaces in effective operative way, and

e) said pump light enters said pump head and said optical duct means, multiply and repeatedly passes through said first optical fiber means via one or two said major surfaces until said pumping light is absorbed by said rare-earth-doped core;

(2) a second optical fiber means, wherein

a) said optical fiber is being winded wrap by wrap, and then preferably layer by layer, to form said second optical fiber means,

b) said second optical fiber means is filled with an optical clear filler which has a refractive index same as or close to the outside cladding of said optical fiber to protect pump optical paths from distortion,

c) said second optical fiber means is in the shape of a thin plate, or thin disk plate, or thin ring plate and has two major surfaces and at least one minor surface,

d) said optical duct means is interfaced to said minor surface of said second optical fiber means in effective operative way, and

e) said pump light enters said pump head and said optical duct means, multiply and repeatedly passes through said second optical fiber means via said minor surface until said pumping light is absorbed by said rare-earth-doped core; and

(3) a third optical fiber means, wherein

a) said optical fiber is winded onto the outer surface of said optical duct means with an optical clear filler which has a refractive index same as or close to the outside cladding of said optical fiber to protect pump optical paths from distortion,

b) said the shape of said optical duct means is predetermined in favor of pumping process, preferably cylinder-shaped, and

c) said pump light enters said pump head and said optical duct means, multiply and repeatedly passes through said optical fiber until said pumping light is absorbed by said rare-earth-doped core.

16. In constructing said pump head as a laser rod pump head by use of said second multipass formation as recited in claim 9, further comprising the steps of

A. making a laser rod means of said laser medium means;

B. constructing said laser rod means to be received in by an optical duct means and surrounded by a cooling channel means, wherein said optical duct means is in the shape of a cylinder or the like, its exterior has a high optical reflectivity for said pumping light, whereby confining and reflecting said pumping light within said pump head during the entire pumping process;

C. constructing two end cap assemblies for housing and cooling said laser rod and for confining and reflecting said pumping light within said pump head during the entire pumping process;

D. selecting said optical duct means from the group consisting of

(1) graded-index optical duct having a variable refractive index in the radial direction, whereby said pumping light, once entering, to be refocussed by refraction into the center area of said pump head periodically and leading to a large acceptance cone, said pump head is named the **Graded-Index Reflector Pump Head**; and

(2) step-index optical duct having two sleeves with a predetermined radial extent in which the inner sleeve has a lower refractive index than that of the outer sleeve appropriately, whereby said pumping light, once entering, to be continually converged to the center area of said pump head and leading to a large acceptance cone, said pump head is named the **Step-Index Reflector Pump Head**; and

E. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

17. In constructing said pump head as a laser rod pump head by use of said second multipass formation as recited in claim 9, further comprising the steps of

A. making a laser rod means of said laser medium means;

B. constructing said laser rod means to be surrounded by a cooling channel means and then received in by an optical duct means in the shape of a cylinder;

C. constructing a hollow means in the shape of a cylinder with two end cap assemblies, and filling a fluid into said hollow means; wherein said hollow means has a high optical reflectivity for said pumping light whereby confining and reflecting said pumping light within said pump head during the entire pumping process;

D. making optical duct means to be received in by said hollow means and surrounded by said fluid, whereby to form a step-index structure, said pump head is named the **Hollow Step-Index Reflector Pump Head**; and

E. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

18. In the method of claim 17, wherein said hollow means includes at least a first section having a longitudinal axis and a second section having a longitudinal axis; said first section longitudinal axis is parallel to and off-set from said second section longitudinal axis, said pump head is named the **Dube Step-Index Reflector Pump Head**.

19. In constructing said pump head by use of said third multipass formation as recited in claim 9, further comprising the steps of

A. constructing said laser rod means to be surrounded by said cooling channel and then received in by an optical duct means; wherein i) the exterior of said optical duct means has a high optical reflectivity for said pumping light, whereby confining and reflecting said pumping light within said pump head during the entire pumping process, and ii) the exterior of said optical duct means is container-like and, in said transverse plane, has a noncircular cross-section with convex and closed boundary, said pump head is named the **Solid Noncircular-Profile Reflector Pump Head**;

B. constructing two end cap assemblies for housing and cooling said laser rod and for confining and reflecting said pumping light within said pump head during the entire pumping process; and

C. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

20. In constructing said pump head by use of said third multipass formation as recited in claim 9, further comprising the steps of

A. constructing a hollow means, wherein i) the enclosure of said hollow means has a high optical reflectivity for said pumping light, whereby confining and reflecting said pumping light within said pump head during the entire pumping process, and ii) the enclosure of said hollow means is container-like and, in said transverse plane, has said noncircular cross-section with said convex and closed boundary, said pump head is named the **Hollow Noncircular-Profile Reflector Pump Head**;

B. selecting said convex and closed boundary from the group including part of that is a contour of a corner reflector;

C. constructing two end cap assemblies for housing and cooling said laser rod and for confining and reflecting said pumping light within said pump head during the entire pumping process; and

D. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

21. In constructing said pump head as a laser rod pump head by use of said fourth multipass formation as recited in claim 9, further comprising the steps of

A. making a laser rod means of said laser medium means which has a lasing axis and a transverse plane perpendicular to said lasing axis;

B. constructing an optical duct means and a hollow means with two end cap assemblies to form said double-layer reflector means, wherein the cross-sectional outline of said optical duct means matches to said hollow means geometrically in said transverse plane with an interstice, said hollow means has a high optical reflectivity for said pumping light, whereby the unabsorbed said pumping light internally impinges upon an air-to-solid interface from inside of said optical duct means, said pumping light which has angles of incidence larger than the critical angle is going to be totally reflected by the outer surfaces of said optical duct means due to total-internal-reflection, and the remaining pumping light which has small angles of incidence and does not meet TIR condition, is repetitively reflected by said hollow means, whereby confining and reflecting said pumping light within said pump head during the entire pumping process;

C. constructing said laser rod means to be surrounded by a cooling channel means and then received in by said optical duct means, said pump head is named the **Solid Double-Layer Reflector Pump Head**; and

D. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass multipass pumping, laser operation and effective cooling.

22. In constructing said pump head by use of said forth multipass formation as recited in claim 9, further comprising the steps of

A. making a laser rod means of said laser medium means which has a lasing axis and a transverse plane perpendicular to said lasing axis;

B. constructing said laser rod means to be surrounded by an optical duct means which is in the shape of a cylinder;

C. constructing a hollow means and an optical inner sleeve means with two end cap assemblies; and

D. filling a fluid into said pump head between said optical duct means and said optical inner sleeve means; wherein

(1) said hollow means includes at least a first section having a longitudinal axis and a second section having a longitudinal axis; said first section longitudinal axis is parallel to and off-set from said second section longitudinal axis,

(2) said hollow means has a high optical reflectivity for said pumping light,

(3) said inner sleeve means is received in said hollow means, and its cross-sectional outline matches to said hollow means geometrically in said transverse plane with an interstice, whereby forming said double-layer reflector means,

(4) the unabsorbed said pumping light internally impinges upon an air-to-solid interface from inside of said inner sleeve means, said pumping light which has angles of incidence larger than the critical angle is going to be totally reflected by the outer surfaces of said inner sleeve means due to total-internal-reflection, and the remaining pumping light which has small angles of incidence and does not meet TIR condition, is repetitively reflected by said hollow means,

(5) said optical duct means is received in said inner sleeve means, mounted at the center area of said hollow means and surrounded by said fluid so as to form a step-index structure, said pump head is named the **Dube Step-Index Double-Layer Reflector Pump Head**, and

(6) optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass multipass pumping, laser operation and effective cooling.

23. In constructing said pump head by use of said fifth multipass formation as recited in claim 9, further comprising the steps of

A. constructing a spatial filter means in order to form said spatial filter structure, consisting of an lens pair with AR coating, and an HR coated beam block means combined with an aperture, wherein

(1) said spatial filter means is at least an one-dimensional spatial filter,

(2) said lens pair serves as a beam expander or reducer likewise,

(3) said AR and HR coating is at the pump wavelength, and

(4) said aperture is served as said pump entrance means;

B. collimating said pumping light at least in one-dimension before entering said spatial filter means;

C. passing said collimated pumping light through said spatial filter means; and

D. making an arrangement in order to pump said laser medium means, said arrangement is selected from group including

(1) a first arrangement, which additionally comprises the steps of placing a mirror properly tilted to reflect pumping light which is coming from said spatial filter means, wherein

a) said laser medium means is a laser slab and placed between said beam block means and said mirror,

b) said pumping light travels back and forth between said beam block means and said mirror,

c) the backward-going pumping light reflected by said mirror has a small deviation from the original path and then are effectively blocked off and re-reflected by beam block means,

d) said pumping light goes through said laser slab means two roundtrips, and

e) said mirror is selected from group including i) a single mirror, and ii) a mirrored surface on said laser slab; and

(2) a second arrangement, which additionally comprises the steps of placing a corner reflector means to reflect pumping light which is coming from said spatial filter means, and further constructing a noncircular-profile hollow reflector by use of said corner reflector means, said beam block means and a mirror means, whereby confining said pumping light substantially and enhance multipass pumping, wherein

a) said laser medium means is a laser rod mounted within said corner reflector means properly;

b) said lens pair is a cylindrical lens pair, serving as a one-dimensional beam expander or reducer likewise,

c) said aperture is a line-shaped opening,

d) said corner reflector means reflects said pumping light toward said laser rod from four different directions of the top, back, front, and bottom,

e) the backward-going pumping light reflected by said corner reflector means has a detour from the original path and then are effectively blocked off and re-reflected by said beam block means, and

f) said pumping light travels back and forth between said beam block means and said corner reflector means which reflect multiple passes of said pump light through said laser rod, said pump head is named the **Noncircular-Profile Corner Reflector Pump Head**.

24. In constructing said pump head by use of said fifth multipass formation as recited in claim 9, further comprising the steps of

A. constructing a semi-spatial filter means in order to form said spatial filter structure, consisting of a cylindrical lens with AR coating, and an HR coated beam block means combined with an aperture, wherein

(1) said AR and HR coating is at pumping light wavelength,

(2) said aperture is a line-shaped opening, and served as said pump entrance means, and

(3) said pump source means is a linear array laser diode bar means;

B. passing said collimated pumping light through said semi-spatial filter means; and

C. making an arrangement in order to pump said laser medium means, said arrangement is selected from group including

(1) a first arrangement, which additionally comprises the steps of placing a mirror properly tilted to reflect pumping light which is coming from said semi-spatial filter means, wherein

a) said laser medium means is a laser slab and placed between said beam block means and said mirror,

b) said pumping light travels back and forth between said beam block means and said mirror,

c) the backward-going pumping light reflected by said mirror has a small deviation from the original path and then are effectively blocked off and re-reflected by beam block means,

d) said pumping light goes through said laser slab two roundtrips, and

e) said mirror is selected from group including i) a single mirror, and ii) a mirrored surface on said laser slab; and

(2) a second arrangement, which additionally comprises the steps of placing a corner reflector means to reflect pumping light which is coming from said semi-spatial filter means, and further constructing a noncircular-profile hollow reflector by use of said corner reflector means, said beam block means and a mirror means, whereby confining said pumping light substantially and enhance multipass pumping, wherein

a) said laser medium means is a laser rod mounted within said corner reflector means properly;

b) said corner reflector means reflects said pumping light toward said laser rod from four different directions of the top, back, front, and bottom,

c) the backward-going pumping light reflected by said corner reflector means has a detour from the original path and then are effectively blocked off and re-reflected by said beam block means, and

d) said pumping light travels back and forth between said beam block means and said corner reflector means which reflect multiple passes of said pump light through said laser rod, said pump head is named the **Noncircular-Profile Corner Reflector Pump Head**.

25. In the method of claim 9, wherein said laser medium means is a laser slab or laser rod, in order to realize high power operation at a minor laser line desired particularly for producing over 2-W CW red and 1-W CW blue coherent light via intracavity SHG, further comprising the steps of

A. setting a desired output wavelength for said minor laser line;

B. constructing a linear laser cavity; wherein

(1) said laser cavity includes at least two cavity mirrors, and

(2) said pump head is placed within said laser cavity for lasing at said desired output wavelength;

C. producing a gain region with intense pumping within said laser medium means;

D. maximizing the cavity Q factor of said laser cavity for said desired output wavelength;

E. minimizing the cavity Q factor of said laser cavity for undesired laser lines;

F. locating said gain region at an optimum position, preferably at ½ L, ¼ L, ¾ L, 1/6 L and 5/6 L, wherein i) L is designated as the optical length of said laser cavity, ii) within said optimum position there would be the highest possibility for a pair of longitudinal modes with a spatially anti-correlated relationship to take place and to occupy most of said gain region spatially, whereby minimizing spatial hole burning and restraining said gain region available to undesired major laser lines;

G. making said laser cavity have a large enough optical length L to prolong an out of phase region to best match said gain region, wherein within the out of phase region two peaks in the standing wave patterns corresponding to the pair of anti-correlated longitudinal modes are out of phase;

H. setting said gain region have a limited length less than 3-cm to best match the out of phase region, whereby restraining said gain region available to undesired major laser lines;

I. keeping the dopant concentration of said laser medium means as low as possible while keeping the absorption efficiency of said laser medium means high for said pumping light;

J. optionally employing the gain sweeping technique to produce a continuous oscillatory change in the optical length of said laser cavity to cause the standing wave pattern of said desired output wavelength to oscillate as a traveling wave along said cavity optical path such that the standing wave pattern moves through at least the entire gain region for extracting substantially all of the gain from said gain region, whereby only said desired output wavelength is lasing steadily; and

K. Optionally inserting a nonlinear crystal means into said laser cavity for intracavity frequency conversion.

26. In a method in configuring a multipass apparatus by means of an optical TIR-guide disk reflector for thin-disk lasers, and for optical and spectral detection, including particle detection, comprising the steps of

A. by use of a circular or noncircular disk-shaped optical duct means, constructing said reflector to have substantially parallel two main surfaces perpendicular to an axis and an outer surface parallel to said axis, wherein said two main surfaces are exactly same and their size is significantly larger than the thickness between them;

B. entering a light toward the center area of said reflector, wherein

(1) said optical duct means is optically clear to said light, and

(2) said light is directed parallel to and confined between said two main surfaces via total-internal-reflection and undergoes multiple reflections via said outer surface; and

C. in order to confine and reflect said light from said outer surface, selecting an approach from the group including:

(1) first approach, which additionally comprises the steps of making an HR coating selectively covering predetermined portions of said outer surface, and

(2) second approach, which additionally comprises the steps of fitting said optical disk into a heat sink chamber means, whose inwardly facing wall matches to said outer surface geometrically and has a gold coating;

whereby said light, once entering said multipass apparatus and said reflector, multiply and repeatedly passes through the center area of said reflector.

27. In the method of claim 26, in order to making **a thin-disk laser pump head** of said multipass apparatus to have a multipass pumping geometry and to produce and amplify coherent light along said axis direction, further comprising the steps of

A. selecting a pump source means to provide said light as the pumping light, from the group including a diode bar means and a multiple-pump-source means having a single pump wavelength or multiple pump wavelengths, to provide the relevant pumping light for pumping;

B. setting a coupling manner to couple said pumping light to said reflector for pumping, wherein said coupling manner includes optical fiber coupling;

C. constructing a laser chip means to be integrated with or embedded into said optical duct means, wherein

(1) said optical duct means is transparent at both the pump and laser wavelengths and its refractive index is the same as or close to that of said laser chip means, and

(2) a joint approach is used for the joint of said laser chip means and said optical duct means, which is selected from the group including, i) interposing a high temperature optical-grade epoxy or cement, ii) diffusion-bonding, and iii) frit;

D. selecting the shape of said two main surfaces from the group including

(1) a circular shape, wherein i)said HR coating is at the pumping light wavelength and ii) at least one AR coated narrow spectral opening or uncoated narrow opening on said outer surface for inputting the pumping light, said optical duct means is made from the group including

a) regular optical duct, said pump head is named the **TIR-Guide Disk Pump Head**, wherein said laser chip is preferably eccentrically located about said optical duct means,

b) graded-index optical duct, wherein said optical duct means has a variable refractive index in the radial direction, whereby said pumping light, once entering, to be refocussed by refraction into the center area of said pump head periodically and leading to a large acceptance cone, said pump head is named the **Graded-Index TIR-Guide Disk Pump Head**, and

c) step-index optical duct, wherein said optical duct means has two sleeves with a predetermined radial extent in which the inner sleeve has a lower refractive index than that of the outer sleeve appropriately, whereby said pumping light, once entering, to be continually converged to the center area of said pump head and leading to a large acceptance cone, said pump head is named the **Step-Index TIR-Guide Disk Pump Head**, and

(2) a non-circular shape, said pump head is named the **Noncircular-Profile TIR-Guide Disk Pump Head**, wherein i) said HR coating is at the pumping light wavelength, and ii) at least one AR coated narrow spectral opening or uncoated narrow opening on said outer surface for inputting the pumping light;

E. conductively cooling said laser chip means surrounded by said optical disk; wherein i)said optical duct means is thermally connected with its back face to an HR mirror or mirrored surface, ii) said mirror has thin substrate with high thermal conductivity, made from the group including copper, sapphire, undoped

YAG and MgF_2, and iii) said HR mirror or said mirrored surface serves as an end or fold mirror for laser operations; and

F. optimizing the optical and physics properties and performance parameters of said pump head in effective operative way, including the profile, size, geometric shape, location and orientation, refractive index and dopant concentration, whereby facilitating efficient and uniform multipass pumping, laser operation and effective cooling.

28. In the method of claim 26, in order to making **a multipass light amplifier** of said multipass apparatus to amplify coherent light along said axis, further comprising the steps of

A. making said light as a signal input;

B. selecting a pump source means to provide a relevant pumping light to pump a laser chip means in order to amplify said signal input;

C. constructing said laser chip means to be surrounded by and integrated with said optical duct means, wherein

(1) said optical duct means is transparent at both said signal input and said pumping light and its refractive index is the same as or close to that of said laser chip means, and

(2) a joint approach is used for the joint of said laser chip means and said optical duct means, which is selected from the group including, i) interposing a high temperature optical-grade epoxy or cement, ii) diffusion-bonding, and iii) frit;

D. constructing said reflector as an optical container to confine said signal input and optionally said pumping light, wherein

(1) the shape of said two main surfaces has a circular shape,

(2) said signal input, once entering, is confined between said two main surfaces and undergoes multiple reflections in consecutive order clockwise or counterclockwise, and multiple passes through said laser chip means whereby being amplified,

(3) said signal input is amplified until outputed from an exit on said outer surface where is an uncoated opening, and

(4) said HR coating is at said signal input wavelength and an opening on said outer surface for inputting said signal input;

E. setting a coupling manner to couple said pumping light to said laser chip means for pumping, from the group including

(1) a first coupling manner to be used as an axial pumping, wherein said pumping light pumps said laser chip means along said axis, and

(2) a second coupling manner to be used as an centripetal pumping, wherein said pumping light is coupled to said outer surface, after entering, undergoes multiple reflections and multiple passes through said laser chip means until it is substantially absorbed, said HR coating is also at said pumping light

wavelength and at least one AR coated narrow spectral opening or uncoated narrow opening on said outer surface for inputting said pumping light; and

F. selecting an output manner to output the amplified signal input.

29. In the method of claim 26, in order to making **a multipass laser intensified detector** of said multipass apparatus for optical or spectral detection, including multipass absorption and particle detection, further comprising the steps of

A. making said light as a probe laser beam;

B. making the shape of said two main surfaces to have a circular shape with a center hole, wherein said center hole is a detecting region for said detection;

C. constructing said disk-shaped optical duct means as an optical container to confine said probe laser beam, wherein said probe laser beam, once entering, is confined between said two main surfaces and undergoes multiple reflections in consecutive order clockwise or counterclockwise, and multiple passes through said detecting region for said detection;

D. placing a path compensating ring with a proper refractive index at said center hole so as to correct optical path distortion if there is an important difference of the refractive index between said optical duct means and said detecting region, wherein said ring has an anti-reflection coating for said probe laser beam preferably;

E. setting a detected sample, including gas, liquid and particle, within said detecting region properly; and

F. arranging a detecting means and a detecting approach for said detection.

30. In a method by means of minimizing spatial hole burning effect in constructing a solid-state laser with high-power operation at a desired minor laser line, particularly for producing over 2-W CW red and 1-W CW blue coherent light via intracavity SHG, comprising the steps of

A. setting a desired output wavelength for said minor laser line;

B. selecting a pump source means, from the group consisting of a diode bar means and a multiple-pump-source means having a single pump wavelength or the multiple pump wavelengths, to provide a relevant pumping light for pumping;

C. selecting a laser medium means from the group including laser chips, laser slabs and laser rods;

D. constructing a pump head for pumping, housing and cooling said laser medium means, capable of realizing intense uniform pumping;

E. setting a linear laser cavity; wherein

(1) said laser cavity includes at least two cavity mirrors, and

(2) said pump head is placed within said laser cavity for lasing at said desired output wavelength;

F. producing a gain region with intense pumping within said laser medium means;

G. maximizing the cavity Q factor of said laser cavity for said desired output wavelength;

H. minimizing the cavity Q factor of said laser cavity for undesired laser lines;

I. locating said gain region at an optimum position, preferably at ½ L, ¼ L, ¾ L, 1/6 L and 5/6 L, wherein i) L is designated as the optical length of said laser cavity, ii) within said optimum position there would be the highest possibility for a pair of longitudinal modes with a spatially anti-correlated relationship to take place and to occupy most of said gain region spatially, whereby minimizing spatial hole burning and restraining said gain region available to undesired major laser lines;

J. making said laser cavity have a large enough optical length L to prolong an out of phase region to best match said gain region, wherein within the out of phase region two peaks in the standing wave patterns corresponding to the pair of anti-correlated longitudinal modes are out of phase;

K. setting said gain region have a limited length to best match the out of phase region, whereby restraining said gain region available to undesired major laser lines;

L. keeping the dopant concentration of said laser medium means as low as possible while keeping the absorption efficiency of said laser medium means high for said pumping light;

M. inserting a nonlinear crystal means into said laser cavity for intracavity frequency conversions, wherein said nonlinear crystal means is selected from the group including

(1) a regular nonlinear crystal means, and

(2) a periodically poled crystal means with quasi-phase-matching; and

N. optionally employing the gain sweeping technique to produce a continuous oscillatory change in the optical length of said laser cavity to cause the standing wave pattern of said desired output wavelength to oscillate as a traveling wave along said cavity optical path such that the standing wave pattern moves through at least the entire gain region for extracting substantially all of the gain from said gain region, whereby only said desired output wavelength is lasing steadily.